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Rediscovery of the endangered Palos Verdes blue butterfly, *Glaucopsyche lygdamus palosverdesensis* Perkins and Emmel (Lycaenidae)

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Abstract. The Palos Verdes blue butterfly (PVB) was believed extinct for eleven years when a small colony was rediscovered by accident on March 10,1994 at a site from which it had not been recorded earlier. The systematics and natural history of the species (=subspecies for conservation purposes), its historic and present habitat, and plans necessary for its recovery are discussed.

Introduction

The Palos Verdes blue butterfly (PVB) was believed extinct for eleven years when a small colony was rediscovered by accident at a site from which it had not been recorded earlier. The rediscovery on March 10, 1994 was made by the team of Rick Rogers, Timothy Dahlum and Rudi Mattoni while visiting the Defense Fuel Support Point (DFSP) at San Pedro for other purposes. The subspecies was believed extinct by at least two authors, Arnold (1987) and Mattoni (1993). The following paper summarizes information to date for the PVB, its habitat and natural history, outlines recommendations for recovery of the species, and discusses what has been done to date.

Historical perspective

Systematics

The subspecies was described by Perkins and Emmel (1977) from Los Angeles county just prior to its listing among the second group of butterflies to be legally recognized as endangered by the federal Endangered Species Act. The taxon was diagnosed as a subspecies of the silvery blue, *Glaucopsyche lygdamus,* a polytypic species comprised of at least 10 valid subspecies that are usually found in small closed local colonies across most of North American north of Mexico and extending into easternmost Siberia. There it meets with its sister species, *G. alexis*, of which *G. lygdamus* and its suite of subspecies might all be considered subspecies within a large holarctic complex. Nothing is known about the border area of these taxa, but at the very least relationships are complex. The PVB was originally differentiated from its likely sister subspecies, *G. lygdamus australis*, the southern blue, by exclusive use of the milk

Figure 1. Specimens of the PVB and the southern blue showing patterns of UNS variation. PVB right column, southern blue left column, single females of PVB, right, and southern blue, left, showing mean differences in blue overlay on the black ground color. PVB females usually lack all but a trace of basal blue.

vetch or rattleweed, *Astragalus trichopodus lonchus*, a relatively fast flight in comparison to *australis*, an earlier flight period than *australis*, and several wing characteristics including a slightly darker underside ground with larger macules well set off by white halos (Figure 1).

Conservation Interest

The butterfly was geographically circumscribed as a coastal terrace ecotype found only on the southern half of the Palos Verdes peninsula in southern Los Angeles county (Figure 2). The species had high conservation value and was not officially delisted in spite of the strong evidence that the species was extinct after 1983. During this period all building

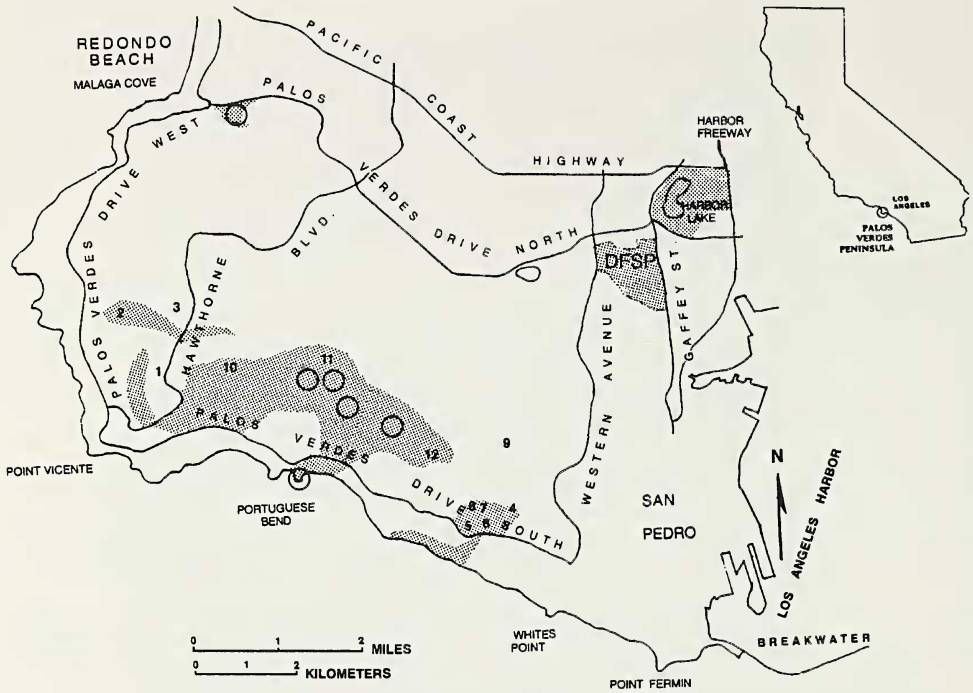

Figure 2. Map of the Palos Verdes peninsula showing the known distribution of the PVB on the south slope before its disappearance, 1979-83. The numbers reference specific sites where the butterfly was observed, see text. Data collected by Jess Morton. The inset map of California positions the Palos Verdes peninsula.

projects in the species distribution area were required to recognize habitat value. The recent find will permit artificial reintroduction of the species into former habitats that can be enhanced following a proper revegetation plan. This will assure both a much higher probable survivability of the PVB and an expanded coastal sage habitat over what now exists across the peninsula.

Distribution

By the time of its discovery in the early 1970's by Perkins, the PVB was already reduced to the few habitat fragments that retained some natural characteristics. In 1981 and 1982 the 12 then known PVB sites were mapped by Jess Morton (Figure 2). The DFSP San Pedro site was unknown. Three of the sites, Hesse Park, Alta Vista, and San Pedro Hill, were razed as habitat between 1978 and 1985, well after they were isolated. The remaining colonies were partially discrete and occurred within three contiguous open spaces that were largely covered with native coastal sage scrub: Agua Amarga (2), landslide moratorium (10, 11, 12), and Palos Verdes Drive East (4-8). Each of the numbered colonies were isolated by anthropogenic land fragmentation and were

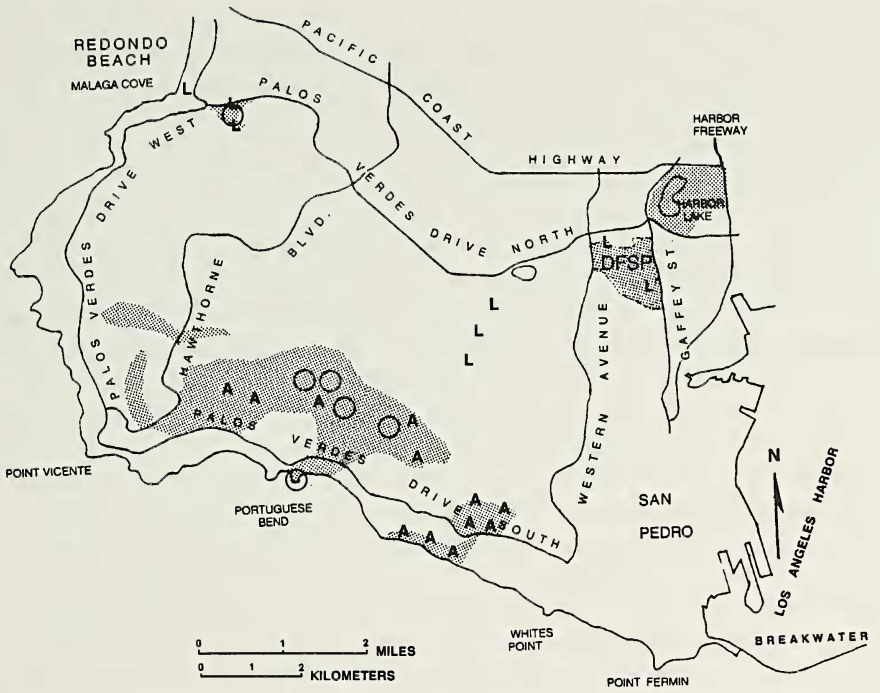

Figure 3. Map of the Palos Verdes peninsula indicating the known distribution in 1994 of Astragalus *tricopodus* (A), *Lotus scoparius* (L), and "open" space that could potentially be restored as habitat. Open space is indicated by stippling. Trapping stations for the general arthropod census are indicated by the circles.

not discrete in the sense of natural metapopulations, possibly excepting the last set. Palos Verdes Drive East was, and to large extent remains, essentially continuous habitat. The last known PVB occurrence was 1983, when Morton and his volunteers noted a few specimens, mostly at Palos Verdes Drive East. There are no earlier data available so the only possible description of distribution is extrapolation from historic plant community information which itself is largely conjectural. Gales (1988) and Brinkmann-Busi (1992) have produced floras of the area.

The largest known populations during the brief time span the PVB was monitored were at Alta Vista Terrace (type locality), Hesse Park, and among the scrub extending from Palos Verdes Drive East to Friendship Park. Alta Vista was built over in 1978. Population sizes were never estimated, but by the early 1980's numbers were extremely low with probably less than 300 adults among all remaining fragments. At Hesse Park in spring, 1982, I counted six adults on the best day, with some 20 foodplants. Each plant had at least 100 eggs, and one plant over 500. Foodplant availability was limiting due to spring discing for fire suppression.

Habitat and ecology

Adult butterflies of all silvery blue subspecies are closely associated with their legume larval foodplants. Recorded foodplants include many species in the genera *Lupinus*, *Vicia*, *Lathyrus, Lotus. Melilotus, Medicago, Oxytropis, Thermopsis,* and *Astragalus* (Scott, 1986). In general, a silvery blue butterfly population at any one locality is restricted to a single plant species. The reason often invoked for this specificity is local adaptation of larvae to particular suites of alkaloids that each plant species presumes to produce for defense. Breedlove and Ehrlich (1972) provided evidence consistent with this hypothesis of coevolution for the case of the Rocky Mountain subspecies of the silvery blue and its *Lupinus* foodplant hosts. However, the general concept of insect/foodplant specificity and the coevolution paradigm is far from convincing (Jermy, 1993 and references).

The PVB is a coastal sage associated ecotype, originally believed restricted to the milk vetch as foodplant. The vetch was largely confined to the summer fog belt characteristic to the southern exposures of the Palos Verdes peninsula at elevations between 100 and 300 meters. The historical area probably occupied by both *Astragalus* and the PVB was about 5000 ha. The flora of the northeast slopes of the peninsula included the low shrub legume, *Lotus scoparius*, foodplant of the sister subspecies *G. lygdamus australis*. The distributions of both vetch and deerweed found in 1994 are mapped on Figure 3. Other open sites of greater size than 20 ha are also indicated, these being potential sites for reintroduction of the PVB after appropriate habitat revegetation. Many smaller fragments remain, but these are too vulnerable to be of conservation value.

Whether *australis* was either historically or recently parapatric with *palosverdesensis* is unknown, although genetic isolation of the subspecies most likely occurred no later than the end of the last ice age, about 10,000 years ago, when the coastal sage scrub of the Palos Verdes peninsula became isolated from the nearest scrubland to the north by the Los Angeles plain and extensive marshland. It is noteworthy that although both the vetch and deerweed occur on Santa Catalina island, the silvery blue is not found there (the butterfly occurs on both Santa Rosa and Santa Cruz). Other biogeographical evidence suggests that Santa Catalina had close affinity to the Palos Verdes peninsula, although there was no physical connection during the past few glaciations.

Causes of presumptive extinction in 1983

In 1983 the last sightings, of between 4 and 7 individual PVB, were made. The discrepancy in number was the likely result of multiple sightings. The number sighted was low by any criteria, supported by many unsuccessful survey days in the field. Thereafter intensive searches by several local lepidopterists were made for several years without success (Arnold, 1987; J. Morton, pers. comm.). The ultimate cause of

extinction was probably destruction of natural coastal sage scrub communities by a combination of development and fire suppression tactics producing ever increasing fragmentation of the remaining natural ecosystem. For organisms with extremely sedentary demographics, population dynamics obviously became disrupted. Some contribution was also made by illegal overcollecting of early stages by a zealous local collector community.

The historic PVB population was likely continuous across the 5000 ha coastal scrub habitat that covered the south half of the peninsula. With intensive development since 1950, habitat was greatly reduced and fragmented, although the 500 ha landslide moratorium area section of open space remains (1994). This section (Figure 3, south-center portion) is not continuous quality habitat, however, but is a mosaic of coastal sage scrub assemblages interspersed with disturbed patches of farmland and otherwise disced and exotic plant contaminated zones. Clearing practices so degraded habitat values for the butterfly that the 1982 construction at Hesse Park, performed by the city of Rancho Palos Verdes in violation of the federal Endangered Species Act, directly destroyed what was probably the second largest remaining PVB colony. The city was subsequently sued by the federal government under the Endangered Species Act, but this legal action was dismissed under the theory that a city could not be held liable.

The proximate cause of PVB extirpation was probably climatic. The winter of 1982-83 was cold and extremely wet, followed by the winter of 1984 that was cold and dry and the beginning of a major drought. With fragmented populations, Hesse Park habitat destruction, and probable overcollecting, the diminished bank of diapausing pupae either did not survive or produced so few adults that maintaining population size was impossible. Simultaneously foodplant numbers declined as well (J. Morton, pers. comm.). Arnold (1987) reported the apparent disappearance of the species and speculated it became extinct. Mattoni (1990, 1993) later concurred with this view.

Current status

Present distribution

Immediately following discovery of the PVB at San Pedro, a thorough search was conducted across all sites indicated on Figure 3; sites where both vetch and deerweed were known. Neither adults or any early stage signs were found on vetch. Presence of either eggs and larvae on the vetch foodplant can be easily observed. The most likely additional localities were hypothesized to be on the stand of vetch at the west end of the landslide area (center of map, Figure 3) and on deerweed in upper Malaga canyon (Figure 3). Observations at both localities were negative. In all likelihood the sole remaining population of the PVB occurs at the San Pedro DFSP.

Regional foodplant distribution

Lotus scoparius is presently found at several localities on the peninsula (Figure 3). Excepting a few plants on the Malaga beach sand dune, all populations are on the north facing slope of the peninsula from Malaga canyon south to the San Pedro DSFP. These populations are associated with the more mesic, dense scrub community of the north slopes. Additional plants may yet be discovered, but these will surely be few and isolated. At San Pedro the majority of plants are found on disturbed sites, either slopes graded within the past few years, mowed roadside, or landscaped slopes.

In contrast, the vetch, *Astragalus tricopodus lonchus*, has only been observed across the south slope of the peninsula in more open xeric coastal sage scrubland. The species is associated with open scrub, implying it may not compete well in establishing within dense mature stands. However, in the most "natural" of the mature scrubland at San Pedro, the species occurs within dense California sage formations. Here mature vetch plants, reaching to nearly a meter in height, are supported by sage branches. The condition permitting occurrence in an otherwise dense cover may be small animal activity (e.g. rabbit trails) that provide periodic openings for vetch seedling establishment. Seeds of *Astragalus* are known to have longevities to a century (R. Snow, pers. comm.).

Presence of the two foodplants together at Palos Verdes is only known at San Pedro. Two exceptions, one vetch in a north slope canyon and one deerweed in the landslide area were observed by Brinkmann-Busi (pers. comm.), but the findings followed several years of observation. The reasons for the usual mutual exclusion are unclear as the two plants are together in the Santa Monica mountains and were both found earlier on the El Segundo sand dunes and coastal prairie. The vetch is always the less abundant species, but seems relatively more abundant where topoclimates are severe.

Bionomics of the PVB

Larvae of the silvery blue are ant tended and usually strongly associated with ant species, three of which were recorded by Ballmer and Pratt (1992). Developing PVB larvae usually feed almost entirely inside rattleweed seedpods, using the seeds for nutrition, this plant part being very high in protein and fat. The presence of a larva within a pod is indicated by an entry hole made by the larva. Larvae have not been observed on deerweed, but they certainly are external feeders on flowers and seedpods because deerweed seedpods are smaller than larvae. Ants specific to the PVB are unknown, but there is unquestionably an ant-larva association. In vetch ants gain access by utilizing the larval entry hole and the larvae are ant tended for the last two instars. At least ten ant species have been found at the new locality to date including two, *Iridomyrex humilis* and *Formica pilicornis*, that are known associates of *Glaucopsyche lygdamus* subspecies (Rogers and Snelling, pers. comm.).

The importance of ants in protecting *G. lygdamus oro* was experimentally demonstrated by Pierce and Easteal (1986) who found 45-84% lower parasitism levels among ant tended larvae. The general phenomenon of ant associations with lycaenid butterflies was reviewed by Fiedler (1991). Determination of the ant hosts should be a high priority given the low surviving PVB population.

The PVB is single brooded. Populations known from the south slope had adult flights recorded from late January into March. Eggs were usually laid on flowerheads of the foodplant, but when foodplant numbers were reduced just prior to the 1982 extinction, eggs were laid over the entire plant. The final generation observed at Hesse Park had larvae feeding on leaves because flowerheads and seeds were exhausted.

Three other Lycaenid butterflies were associated with the vetch flowerhead/seedpod guild: *Strymon melinus, Leptotes marina* and *Everes amyntula*. The first two are polyphagous, have many alternate foodplants, and remain widespread species across the Palos Verdes peninsula as well as globally. The latter is an oligophage that was restricted to *Astragalus* at Palos Verdes. It uses other species of legumes elsewhere. The species was believed extirpated from the Palos Verdes peninsula. After a ten year hiatus, the species was sighted near site 4, Figure 2 in 1995 (G. Pratt, pers. comm.).

The western tailed blue, *Everes amyntula*, occurs on at least four channel islands, including Santa Catalina. In contrast *Glaucopsyche lygdamus* is only found on two islands. Given the pattern of foodplant distribution with both deerweed and vetch found on the four islands of occurrence, it is unclear why the silvery blue is not found on all the islands. Its potential capability of using two foodplants would provide greater buffering against adverse conditions and is certainly the factor responsible for survival of the PVB at San Pedro while the western tailed blue was lost.

We first observed PVB females at San Pedro ovipositing on deerweed, exclusively using flowerheads. Later Rogers saw females ovipositing on vetch and discovered eggs on vetch inflorescences. Eggs are easily observed on flowers and seedpods in contrast to those on deerweed. We have no information on selectivity of individual females to either plant. It has recently been demonstrated for other butterflies that individuals exhibit behavioral specificity in the presence of multiple foodplants (review in Papaj and Lewis, 1993).

Two other dominant spring flying butterflies at the site, the California green hairstreak (*Callophrys affinis perplexa*) and the funereal dusky wing (*Erynnis zarucco funeralis*), both use deerweed as foodplant. However, their larvae are leaf feeders and thus avoid interference competition with early stages of the PVB. Females of these species deposit eggs upon stems and leaves. Hairstreak larvae are not ant-tended lycaenids.

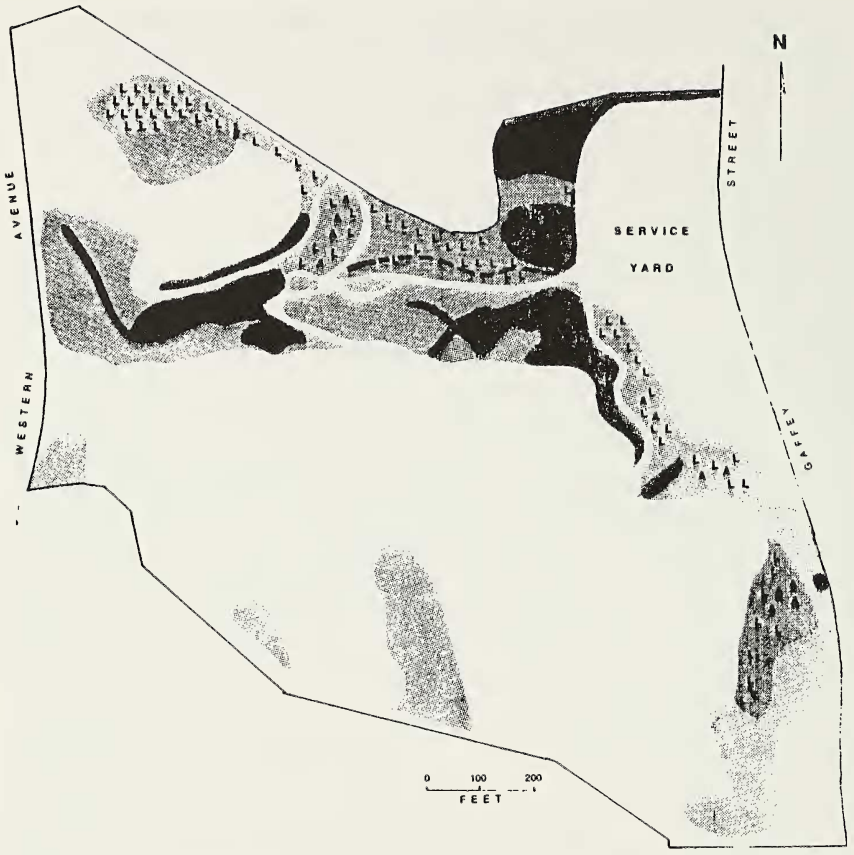

Figure 4. Map of the San Pedro DFSP presenting an overview of "native" habitat (heavy stippling) and degraded open space habitat that has potential for restoration (light stippling). Locations of individuals or stands of Astr*agalus tricopodus* and *Lotus scoparius* are indicated by the letters A and L respectively. The clear areas position underground storage tanks and are unsuitable for revegetation. The broad line extending from Western Avenue easterly, dashed in the central portion, indicates the riparian seasonal stream with mature willows (solid line) and sporadic *Baccharis* (dashed line).

The San Pedro colony

While setting out and servicing pitfall and yellow pan traps in late 1993 for a regional arthropod survey we noted that the DFSP San Pedro site did not appear likely to support a PVB population. Discovery of the PVB at all was unexpected. PVB use of deerweed was unknown and the vetch population we noted was a cluster of fewer than 25 individuals. We subsequently found a second cluster with another 30 individuals. A proximate vegetation map of the site (Figure 4) shows the distribution of deerweed, vetch, and coastal sage scrub across both relative "natural" and disturbed open space. The latter areas should be revegetated to create a coastal sage plant community and augmented habitat.

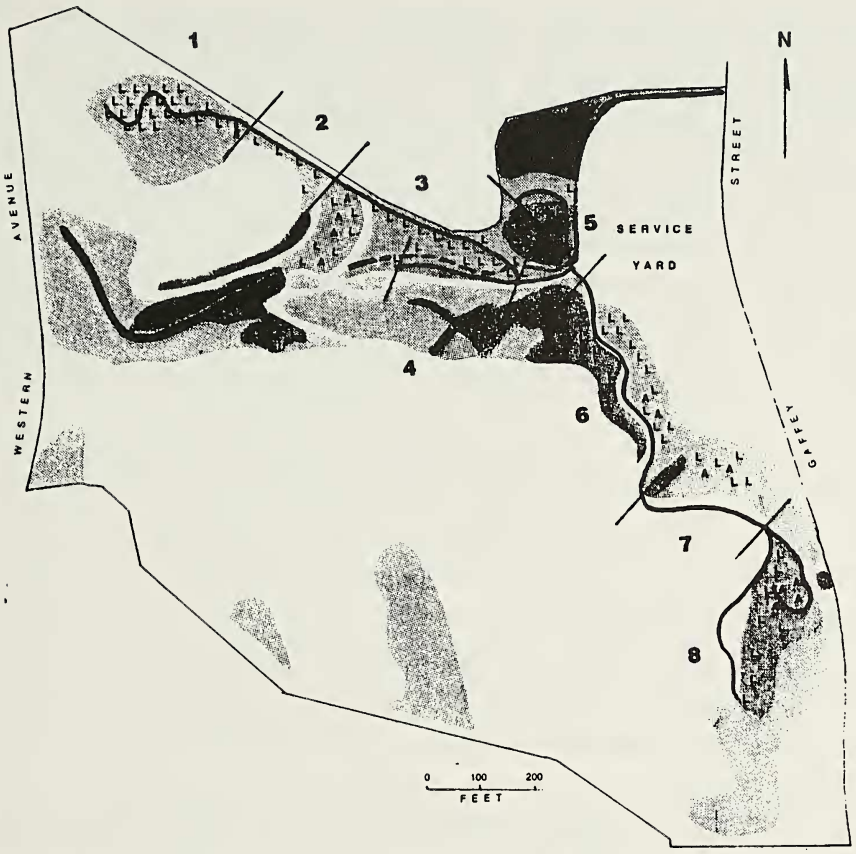

Figure 5. Map of butterfly transect, pitfall traps, and yellow trap stations at San Pedro DFSP, superimposed over figure 6. Eight segments of the transect are indicated by lines drawn across the transect with the segment number given. Segments 4, 5, and 8 required retracing of the walk over all or part of the transect segment. Counts were only recorded on the outbound walk on those portions of the segment.

After sighting the butterfly and notifying the U.S. Fish and Wildlife Service, we immediately instituted a transect walk survey to provide semi-quantitative data on the PVB. Figure 5 is the vegetation map with an overlay showing the transect route selected for observing the PVB (and other readily identifiable insects) as well as the locations of trapping stations. Only the westerly two trap stations were in operation when the butterfly was discovered. We have since expanded our survey plan for the site.

PVB population size and distribution

The transect was delineated to traverse the majority of foodplant concentrations (Figure 5). No PVB were observed beyond the envelope of foodplants. We assumed the species to be highly sedentary and seldom

moved beyond foodplant sites by more than a hundred meters. All tests with related species of blue butterflies demonstrated restricted flight ranges (Arnold, 1983; Pollard and Yates, 1993; Keller et al. 1966).

The transect was sampled by one individual, R. Rogers, about three times a week from March 12 to April 11. Data were recorded on a small scale map where every visually identifiable insect was noted. The transect was about 950 m (3050 ft) in length. Individuals recorded included all in view, usually within 10 meters either in front of or alongside the observer. The usual 5 m square forward "projected box" of the Pollard method (Pollard and Yates, 1993) would have yielded too few observations. Care was exercised to not record any insect twice on any transect leg. The observer was highly trained and experienced in the methodology.

The data are given in Table 1, including two other butterflies in flight during the time period, the California green hairstreak and the funereal dusky wing. Sampling was made in the morning and afternoon on most days. The last PVB was sighted April 8, with an exception seen by J. Morton on April 23. A total of 13 days were sampled for a total of 24 samplings. For analysis the transect was arbitrarily divided into 8 segments, shown on Figure 5. Each segment was fairly uniform with respect to vegetation and slope, characteristics briefly stated on Table 1. The number of individual male and female PVB, hairstreaks, and dusky wings are presented with their relative frequencies along each transect segment.

The results show a highly significant nonrandom distribution of the three most common spring butterflies among the different transect segments. A most striking feature was segment 1, which represents an early succession vegetative cover with deerweed dominant and forming an almost pure stand in the shrub profile: the PVB was not seen at all, while the California green hairstreak occurred on no other segment. Segment 2 was low quality habitat and probably served only as a corridor, if not a barrier. Even the dusky wings were not observed while they otherwise were randomly distributed across all other segments.

The PVB had its highest occurrence where deerweed was robust (segments 4, 6 and 7) and vetch relatively abundant (6). The low female sex ratio (0.26) is not unusual among lycaenids in nature and is in all likelihood a sampling artifact. Females are less vagile, devoting most time to siting oviposition locations. The absence of PVB from the segments 1 and 2 implies sensitivity to the low cut sward of 2 that may form an absolute barrier to movement .

Because of methodological defects in using marking as a demographic tool with lycaenid butterflies (Murphy, 1988) and acute concerns when they are endangered, population size estimates can only be crudely approximated by using transect counts. If we assume the maximum number counted on the best of the two walks are each different individuals, each set between days sampled represent new eclosions, that the

Table 1. Total number of butterflies observed on the transect walks at the San Pedro DFSP, March 12 through April 11, 1994. An additional female was seen on the site by another observer on April 23 and another transect walk was made April 29, at which time all spring species were absent. Three spring species are included, with males and females indicated for the Palos Verdes blue, *Glaucopsyche lygdamus palosverdesensis* (PVB). The other two species are the funereal dusky wing skipper, *Erynnis zarucco funeralis* (FUN) and the California green hairstreak, *Callophyrs affinis perplexa* (CAG). The length of each transect segment is given in meters as is both total number (numerator) and relative frequency (denominator, boldface) of each category along each segment (number/meters).

Segment	Description of habitat	length (m)	PVB ♂	PVB ♀	FUN	CAG
1	in early succession, predominant *Lotus scoparius* excavated soil deposit, sandy,	150	0	0	22 **.15**	21 **.14**
2	open mown corridor, Mediterranean grass with few seedling *L. scoparius*	65	1 **.01**	0	0	0
3	disturbed pipeline right-of-way, dense *L. scoparius* growth, *Encelia* present, the entire section does not appear natural	130	4 **.03**	3 **.02**	9 **.07**	0
4	slope appears unnatural with high clay, rocks, and rubble, buckwheat appears planted, few *L. scoparius* robust	70	15 **.21**	4 **.06**	1 **.01**	0
5	natural appearing coastal sage slope, few *L. scoparius,* robust, shrub community diverse	100	9 **.09**	9 **.09**	2 **.02**	0
6	east side of road myoporum landscaped slope with mix of *L. scoparius* and *Astragalus*, west side native dense coastal sage	145	39 **.27**	10 **.07**	21 **.15**	0
7	contoured slope landscaped with sparse myoporum, interspersed with *L. scoparius* and *Astragalus.*	115	12 **.10**	7 **.06**	22 **.19**	0
8	dense native coastal sage scrub with sparse *L. scoparius* and *Astragalus.*	175	0	0	3 **.02**	0
Totals		950	80 **.08**	29 **.03**	117 **.13**	21 **.02**

numbers of females is the same as males, and that we only observed 20% of the real population, then Nt would be about 300 and Ne somewhat less. This is likely an overoptimistic value.

Conservation planning

By any measure this last remaining population of the PVB is small and in jeopardy of extinction from stochastic processes at any time within the next decade. Because of the degraded statė of remnant natural habitat at the DFSP, it will be necessary to implement a habitat conservation plan as rapidly as possible. As an emergency step we recommend an immediate captive breeding program be instituted to both guarantee that the population is not lost and to provide a significant increase in numbers for later release at former known sites of occurrence. Methodology for mass rearing the PVB was developed a decade ago using the southern blue as a surrogate in hopes of then preventing extinction of the PVB (Mattoni, 1988). Recovery of the species will only be possible by establishing several discontinuous colonies distributed across all large remnants of the butterfly's former range.

Habitat revegetation

The first step towards recovery will be to maximize survival potential for the butterfly at the San Pedro DFSP. The fundamental philosophy will be a coastal sage community revegetation plan that emphasizes ecosystem integrity and not single species requirements. Preliminary discussion with DFSP indicates that land will be available for restoration. About 100 acres of the site are suitable (Figure 4) including the approximate 30 acre native plant community fragments. The latter provide both model data for a restoration plan and a source of propagules for restocking.

The proximate general plant community cover was mapped by Brinkmann-Busi and Mattoni to provide one basis of habitat restoration. Brinkmann-Busi prepared a detailed inventory of the flora, surveyed several 100 m transects that indicate plant densities across the major topological aspects of shrub cover, and completed detailed vegetation maps of the area involved with pipeline maintenance. Replacement of a major pipeline that bisects the butterfly population on site 3 was underway when we first found the PVB. Completion of construction is necessary as the least damaging alternative for the site because the original pipe was near failure, an environmentally unacceptable event that would release large quantities of petroleum product into the habitat. Construction can continue with virtually no impact on the PVB or other natural values and will provide greater overall habitat value if care is taken to minimize impact on the butterfly and the area is correctly revegetated.

Regional reintroduction

The ultimate goal will be to reintroduce the PVB into all of its former sites. Before this can be successfully undertaken, however, the plant communities must first be substantially enhanced with special attention given to their nuances of assembly relative to topoclimates and substrates. Accurate vegetation maps are necessary for this purpose, but many political hurdles need to be addressed including regional planning. An attempt is underway to establish a Natural Community Conservation Plan (NCCP) for the Palos Verdes peninsula to shape habitat conservation in the region. Until there is political resolution of a rather convoluted land use situation that involves participation of five municipalities, further biological discussion is not useful except to point out that the PVB is one of the few known Palos Verdes endemics and must be reckoned with under present laws.

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